N.I. 3.2b

12-13-78

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(NASA-CR-158172) DEVELOPMENT OF AN IMPROVED HIGH EFFICIENCY THIN SILICON SOLAR CELL Quarterly Report (Solarex Corp., Rockville, Md.) 10 p HC A02/MF A01 CSCL 10A

N79-19459

Unclas

G3/44 18692

DEVELOPMENT OF AN IMPROVED HIGH EFFICIENCY THIN SILICON SOLAR CELL

JPL CONTRACT NO. 954883

JULY, 1978

THIRD QUARTERLY REPORT

REPORT NO. SX/115/3Q

BY

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This work was performed for the Jet Propulsion Laboratory, California Institute of Technology sponsored by the National Aeronautics and Space Administration under contract NAS7-100.

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TECHNICAL CONTENT STATEMENT

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Abstract

Efforts in this quarter were directed towards investigating means of producing more effective high-low junctions at the back of the cell. Cells with output power up to 77 mW (AM0 efficiency of 14.2%) have been fabricated. Some reflectivity studies were also made. Deliveries of 2cm x 2cm experimental cells to JPL have included a number having AM0 outputs greater than 70 mW.

SUMMARY

The principal goals of the work under this contract are to improve the efficiency of experimental ultra thin solar cells and to fabricate such cells on a Pilot Line basis. During the past quarter, the major effort on the experimental cells has been directed towards increasing the open-circuit voltage by improving the back surface field. This effort has resulted in $4cm^2$ cell of 50 μm thickness having a maximum AM0 efficiency of 14.2% (peak power of 77 mW) at 25°C. Alloying of evaporated aluminum at higher temperatures has been responsible for the increases power and open circuit voltage. Back surface texturing s found to have little influence on output power and back face reflection.

Technical Discussion

A. Experimental Cells

1. General -- We are continuing to fabricate ultra thin cells using techniques developed during earlier portions of the contract period. Specifically, all cells are being diffused with their front sides convex, and surface texturing for spectral response enhancement is being accomplished by a second etching of the thinned slices in an isopropyl alcohol - KOH solution after thinning in a NaOH + H_2O solution. During the latest quarter, we have begun to investigate different methods of creating a back surface field with the goal being an increase in open-circuit voltage to over 0.6 V for 0.05 mm cells.

2. Back Surface Field Experiments -- In experiments with 0.025 cm thick cells, it was found that as the temperature at which evaporated aluminum was alloyed was increased, the open circuit voltage also increased. However, the long-wavelength response suffers with higher alloy temperatures employed for times of 10 minutes or 20. Consequently, aluminum was evaporated on slices and alloyed for a very short time ($\sim$30 seconds) at 1050°C. Two different thicknesses of aluminum were investigated, namely, 1 μm and 2 μm. Typical results are shown in Table I. As can be seen, many cells were fabricated with AM0 output power exceeding 70 mW. The best cell had an output power of $\sim$77 mW without coverslide (Figure 1). This and the other cells showed a high blue response combined with an appreciable red response. A

higher incidence of junction shunts was observed in cells on which 2 μm of Al had been evaporated, primarily because aluminum had locally agglomerated and fused through to the front of the slice during alloying.

Another aspect of the experiments was to compare cells fabricated with textured back surfaces to cells with masked untextured backs. The results obtained from some 2 Ω-cm Wacker float-zone silicon are seen in Table II. The open circuit voltage is not significantly different when the two are compared. However, there is a difference in short-circuit current. Reflectivity and capacitance measurements indicate that the higher-current cells have a greater degree of front surface texturing. Therefore, the surface morphology of the back does not appear to have a major influence on the output power. Experiments are continuing so that the open circuit voltage can be increased. Various methods of putting aluminum on the slice back and forming the alloy are being tried.

3. Reflectivity Studies -- A surprising aspect of the results obtained on textured and untextured backs is the high currents obtained even though reflectivity from the back surface is low. Figure 2 shows the reflectivity spectrum for cells having textured and untextured backs. The reflectivity for both remains at less than 20% for long wavelengths. It is expected that an increase in current would result if a more highly reflective back contact can be made. We plan to re-evaporate Al (as has been tried by other workers) in order to increase the back reflectivity.

TABLE I

Characteristics of Cells with Aluminum Backs Alloyed at 1050°C

Lot #	I_{sc}	I_{sc}^{blue}	I_{sc}^{red}	V_{oc}(25°C)	P_{max}	Comments
2831-2	166mA	52mA	81mA	585mV	77mW	Untextured
	165	52	80	583	76	Back; 1 μm Evaporated
	156	51	73	569	69	Al; 2Ω-cm
	159	51	75	571	70	Monsanto Si
	166	52	81	578	76	
2831-5	159	53	76	569	69	Textured
	156	52	73	563	69	Back; 1μm Evaporated
	156	53	73	562	70	Al; 2Ω-cm
	155	52	73	564	70	Monsanto Si
2831-3	162	51	79	566	72	Untextured
	162	51	79	566	69	Back; 2μm Evaporated
	163	51	81	566	71	Al; 2Ω-cm
	164	51	81	565	72	Monsanto Si
2831-6	159	47	80	569	69	Textured
	163	52	79	578	73	Back; 2μm Evaporated
	162	51	79	577	71	Al; 2Ω-cm
	162	52	81	567	68	Monsanto Si

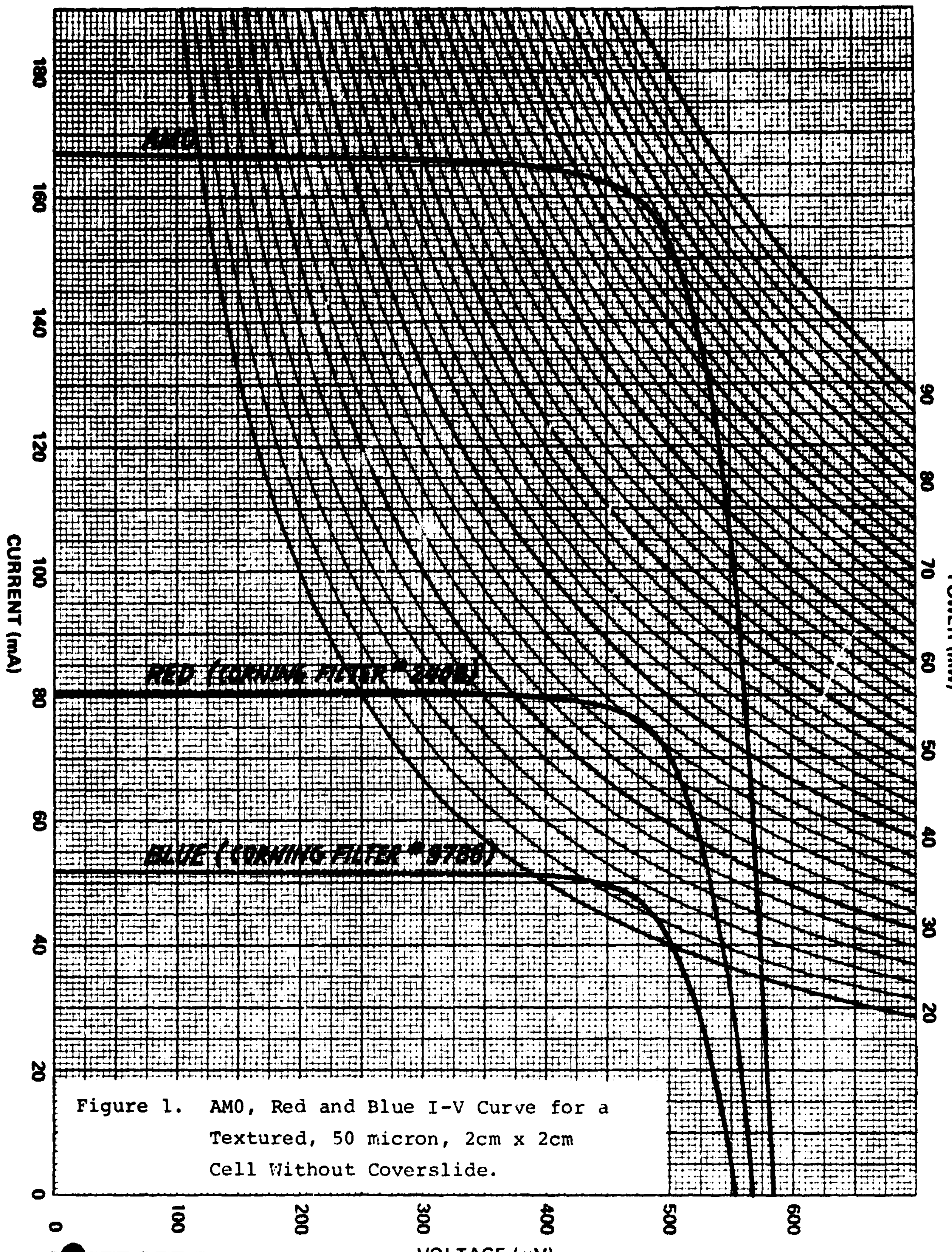

Figure 1. AM0, Red and Blue I-V Curve for a Textured, 50 micron, 2cm x 2cm Cell Without Coverslide.

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Cell Type TEXTURED 2-MIL No. 2831-2-1 By TT Date 6-27-78

TABLE II

Comparison of Electrical Characteristics of Cells Having Textured and Untextured Backs.

1. Untextured Back - Lot # 2831-7

Cell #	I_{sc} (mA)	V_{oc} (mV)	P_{max} (mW)
1	157	584	72
2	160	583	74
3	157	584	73
4	158	582	74
5	159	581	74
6	162	587	75
7	159	583	74
8	160	584	75
9	160	584	74

2. Textured Back - Lot # 2831-8

Cell #	I_{sc} (mA)	V_{oc} (mV)	P_{max} (mW)
1	167	588	73
2	167	587	70
3	166	588	71
4	166	588	75

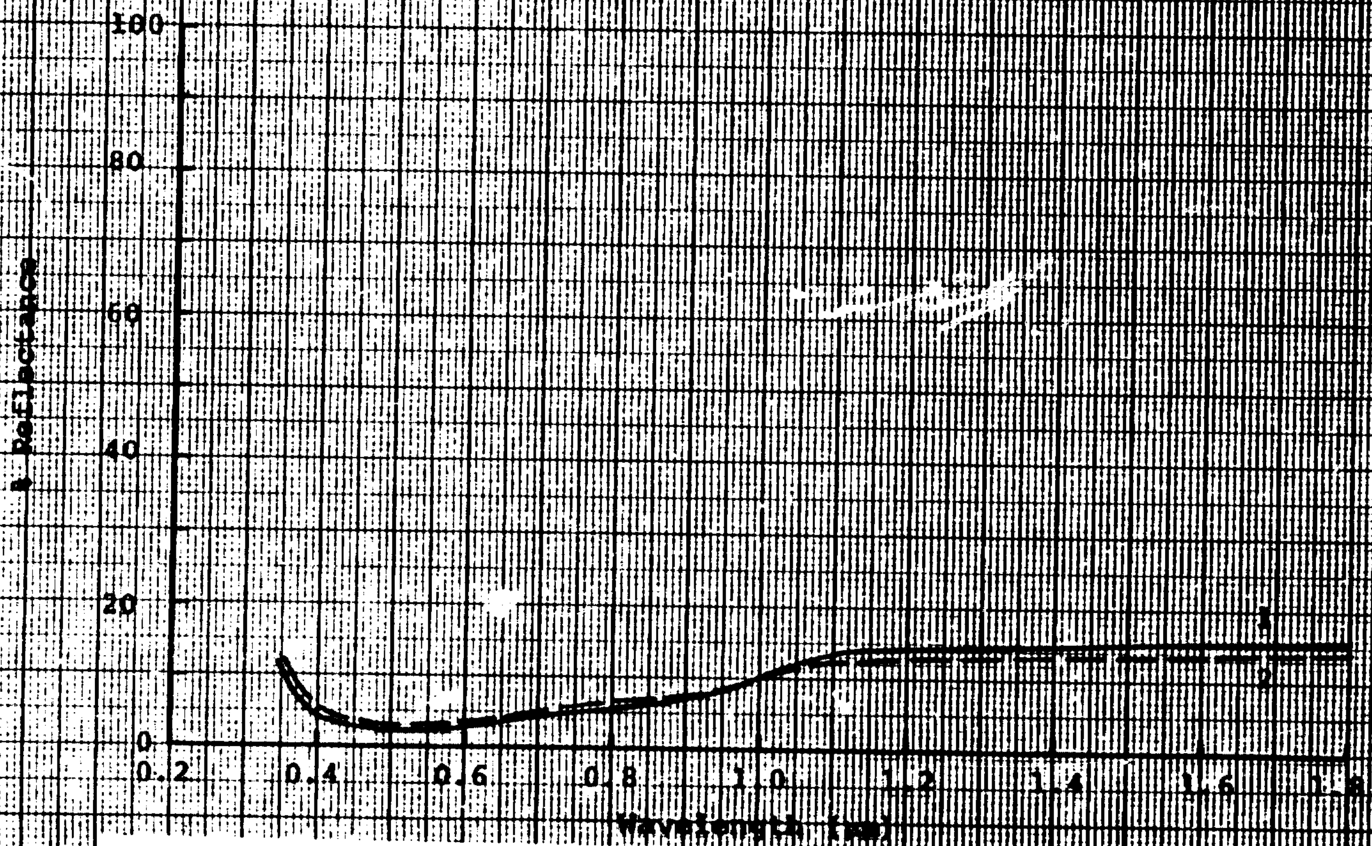

Figure 2. Spectral Dependence of the Reflectance for ultra thin Cells with 1) Textured Back and 2) Untextured Back.

PLATED PALLADIUM - PLATED COPPER PROCEDURES

1) Standard 2x2 cm substrates

2) Photoresist and etch

3) Immersion Pd bath (Appendix E)

   A) Five (5) seconds 10% HF

   B) Immersion Pd bath - 3 minutes

   C) Scrub with Q-tip, DI H_2O rinse

   D) Heat treat 400°C in N_2 - 15 minutes

4) Electroless Pd bath (Appendix E)

   A) Five (5) seconds in 10% HF

   B) Immerse in bath for 2 minutes at 40°C

   C) Heat treat 400°C in N_2 - 5 minutes

5) Electroless Cu bath (Appendix B), for 2 minutes

6) Electrolytic Cu bath (Appendix D)

   A) Thirty (30) minutes at 30 ma for 4-o μm layer.